EDUCATION
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ORIGINAL ARTICLE

Brief, cooperative peer-instruction sessions during lectures enhance student recall and comprehension*

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Objective: The objective of this study was to evaluate the academic impact of cooperative peer instruction during lecture pauses in an immunology/endocrinology course.

Methods: Third-quarter students participated across iterations of the course. Each class offered 20 lectures of 50 minutes each. Classes were divided into a peer-instruction group incorporating cooperative peer instruction and a control group receiving traditional lectures. Peer-instruction group lectures were divided into 2–3 short presentations followed by a multiple-choice question (MCQ). Students recorded an initial answer and then had 1 minute to discuss answers with group peers. Following this, students could submit a revised answer. The control group received the same lecture material, but without MCQs or peer discussions. Final-exam scores were compared across study groups. A mixed-design analysis of covariance was used to analyze the data.

Results: There was a statistically significant main effect for the peer-instruction activity ($F(1, 93) = 6.573$, $p = .012$, $r = .257$), with recall scores higher for MCQs asked after peer-instruction activities than for those asked before peer instruction. Final-exam scores at the end of term were greater in the peer-instruction group than the control group ($F(1, 193) = 9.264$, $p = .003$, $r = .214$; question type, $F(1, 193) = 26.671$, $p = .000$, $r = .348$).

Conclusion: Lectures with peer-instruction pauses increase student recall and comprehension compared with traditional lectures.

Key Indexing Terms: Active Learning; Chiropractic; Education; Teaching

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INTRODUCTION

Active-learning strategies are increasingly advocated in academia; Bonwell and Eison[1] noted that these include a wide range of activities sharing the common element of "involving students in doing things and thinking about the things they are doing." Education researchers report that students learn more when they are actively involved in learning than when they are passive recipients.[2–4] Active involvement in the learning process is thought to enhance creative thinking, judgment, interpretation, and problem-solving skills.[3,5,6] Active involvement has also been shown to improve student conceptualization of complex systems and increase retention.[7–9]

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Problem-based learning (PBL), team-based learning (TBL), and cooperative peer instruction (CPI) are all active-learning strategies that utilize small-group discussion. PBL is a student-centered pedagogy in which students learn course material by solving open-ended problems in self-directed, small-group exercises.[10] After receiving an exercise problem, group members identify what they already know, what they need to know, and how and where to access new information that may lead to resolution of the problem. The course instructor facilitates learning by supporting, guiding, and monitoring the learning process. This teaching method was developed by Barrows and colleagues at the McMaster University Medical School in Canada in the late 1960s and is now used in primary, secondary, and tertiary education systems around the world.[11,12]

TBL is an active-learning method that was developed to apply the benefits of small-group learning in large business classes.[13] The course instructor typically assigns students to teams of 5–7. TBL is characterized by 5 consecutive phases[13,14]: (1) individual preparation prior to the instructor's in-class presentation of material; (2) brief, 5–15 multiple-choice question, individual readiness assurance tests; (3) immediate retake of the same brief assurance test, but this time as the assigned team; (4) presentation of post-assessment, written appeals on questions missed by the team that are supported by assigned class reading materials; and (5) in-class application exercises performed by the teams that are reported to the whole class and evaluated at that same time by the instructor. In addition, team participation is incentivized by class points awarded for team activities (team-based repeat of the readiness assurance test, subsequent team-based content application exercises, and "team maintenance" points [class points awarded to all teams that may be withheld from a team member if the team collectively determines that member was not adequately contributing to the team]). TBL was introduced in medical education in 2001 as a learner-centered but instructor-led learning strategy.[15] Until that time, case-based and problem-based materials were presented in a classical lecture. TBL is commonly applied with a course instructor performing dual roles: expert content provider and overseer of small-group learning exercises.[16]

Peer instruction is a common component of both PBL and TBL, but it may be used by itself, without the additional elements that characterize PBL and TBL. In this case, it is generally referred to as CPI. A class taught with CPI is divided into a series of short presentations, each focused on a central point and followed by a question that probes student recall or comprehension of the ideas just presented. Students are given 1–2 minutes to formulate individual answers and report those answers to the instructor. The students then discuss their answers in small peer groups. The peer discussion typically lasts 2–4 minutes, after which the instructor again asks the students to report their answers, which may have changed based on the discussion.

In this paper, we report the academic impact of CPI exercises applied as "lecture pauses" during an immunology/endocrinology course at our chiropractic college.

In a seminal study, Stuart and Rutherford (1978) [17] reported that student concentration rose to a maximum in 10–15 minutes and then fell steadily until the end of the lecture. Subsequently, McLeish (1984) reported that students retained 41% of the content presented during the first 15 minutes of class, 25% after a 30-minute class period, and only 20% after a 45-minute period.[18–21] Ruhl[22] advocated that lecturers use a "pause procedure" to enhance student understanding and information recall. He described the pause procedure as a strategy for transforming lectures into interactive activities. It calls for a 2-minute period of discussion or note taking at least 3 times during a 50-minute class. Students hearing lectures in which the instructor paused to allow discussion performed significantly better on both free-recall quizzes and comprehensive tests.[22]

Unfortunately, active-learning strategies are often not used in large classrooms.[23,24] Instructors cite limited class time, increased preparation time, and a lack of needed resources as reasons for not incorporating these activities in the classroom. Instructors are also reluctant to change what has worked for them without substantial documentation that a different method is more effective. CPI has been used successfully to transform otherwise passive lectures into active-learning activities.[25–27]

Therefore, we decided to evaluate the effectiveness of a CPI exercise in an immunology/endocrinology course at our chiropractic college. This course is offered in the 3rd quarter of a 13-quarter program. For hypothesis 1, we hypothesized that students would improve their responses to multiple-choice quiz questions administered during CPI activities, and these improvements would be differentially affected by question type (recall vs comprehension). We also anticipated that students in classes with CPI activities would demonstrate greater retention and comprehension of lecture material evaluated via a cumulative final exam, compared with students in classes receiving traditional lectures without CPI activities (hypothesis 2).

METHODS

Student Participants

Palmer College of Chiropractic institutional review board granted this educational-method study an exemption from formal review. Permission was obtained from all students to use de-identified performance assessments for this study and subsequent publications.

A total of 198 3rd-quarter students participated in the study across 4 consecutive iterations of a 3-credit class presenting immunology and endocrinology content (April 2013 to March 2014). Each class offered 20 lectures of 50 minutes each. Two classes ($n = 58$ and $n = 44$, totaling 102 students) served as the peer-instruction study group, incorporating active-learning exercises. The other 2 classes ($n = 34$ and $n = 62$, totaling 96 students) served as a control study group, receiving a traditional lecture format (passive learning).

Course materials were equivalent for all 4 classes. The same instructor (NZ) taught the 4 classes, taking care to cover the same material with proportional class time allocation. A comprehensive final exam was given at term end for each class. Demographic data (sex, age, academic degrees, and ethnicity) were also collected.

Multiple-Choice Question Bank

The course instructor (NZ) developed a bank of "single best response" multiple-choice questions (MCQs) testing immunology and endocrinology learning. These were categorized into 2 question types in accordance with Bloom's *Handbook on Formative and Summative Evaluation of Student Learning* (1971).[28] The question types were recall questions and comprehensive questions. Recall questions require the student to recall factual information from memory and are generally used to test mastery of basic information. A recall question might ask, "What are the types of immunity?" Comprehension questions evaluate the student's ability to grasp the meaning of facts and ideas by translating material from one form to another (words to numbers), interpreting material (explaining or summarizing), or estimating future trends (predicting

Table 1 - Demographics for Study Subjects ($n = 198$)

Study Group	Peer Instruction[a] ($n = 102$)	Control[a] ($n = 96$)
Sex		
Male	55 (54)	61 (64)
Female	47 (46)	35 (36)
Academic degree		
Bachelor	98 (96)	88 (92)
Graduate	4 (4)	8 (8)
Age		
<30 y	95 (93)	70 (73)
30–40 y	6 (6)	20 (21)
>40 y	1 (1)	6 (6)
Ethnicity/race		
Caucasian	83 (81)	68 (71)
Hispanic	10 (10)	6 (6)
Black	3 (3)	8 (8)
Other	6 (6)	14 (15)

[a] Student counts in each study group, with numbers in parentheses being within-group percentages (%).

consequences or effects). A comprehensive question might provide clinical information pertaining to immunity and then ask, "Which of the following lab values would you expect in this patient?"

All MCQs were reviewed carefully and validated by a faculty content expert not involved in teaching the classes. After evaluation and validation, the MCQs were subgrouped according to question type (simple recall vs comprehension) to produce a quiz question bank for the 20 class lectures. The peer-instruction activity quizzes and the cumulative final exam tested student learning on the same topic material but did not contain replicate MCQs.

Procedures

In the peer-instruction study group, a cooperative peer-instruction technique was used for 20 immunology and endocrinology lectures. Each 50-minute lecture was divided into 2–3 short presentations of 15–22 minutes each. Each brief presentation was followed by a single quiz question that focused on the information presented. Students were allowed 1 minute to think and to record their answers. Subsequently, students were allowed an additional 1 minute to discuss their answers with neighboring peers. Following this peer discussion, students could change their answers if desired, and both answers (pre- and post-discussion) were collected. Prior to the peer-to-peer discussions that occurred during the peer-instruction exercise, students were not told whether their first responses were correct or incorrect. Consequently, responses to the second presentation of the quiz question were informed only by the peer-instruction exercise. Finally, the instructor and students discussed the correct answer to the quiz question.

The control study group received coverage of the same lecture material over the 50-minute class period but without the quizzes or peer discussions.

Data Analysis

Data were examined graphically to reveal underlying distribution patterns and identify outliers. We summarized and analyzed our data using SPSS version 22 (IBM Corporation, Armonk, NY). Statistical-test assumptions were verified, and standardized effect sizes and 95% confidence levels were calculated. Study hypotheses were evaluated at a .05 family-wise alpha level.

We employed a mixed-design analysis of covariance (MD-ANCOVA) with planned contrasts to examine whether students in the peer-instruction study group improved their quiz answers following the cooperative peer-instruction exercises, and whether question type—recall vs comprehension—was an important factor (hypothesis 1). Sex and ethnicity/race were examined as potential between-group explanatory factors. Degree held is reported here as a demographic value but was not included as a factor in the study analyses because too few individuals held graduate degrees for meaningful comparison. Similarly, age was highly skewed in the study population. It was collapsed into 3 age groups for demographic reporting but was included in all analyses only as a continuous covariate to hold its influence constant. We also applied an MD-ANCOVA to evaluate the cumulative final-exam scores of students receiving lectures with CPI compared with students receiving traditional lectures without CPI (hypothesis 2).

We examined question type (simple recall vs comprehension) as a within-group factor and study group, sex, and ethnicity/race as between-group factors. As stated above, degree held was not included in the analysis, and age was included as a covariate to hold its influence constant.

RESULTS

Demographic Information

Students were nearly equally divided between peer-instruction and control study groups (102 and 96, respectively). Comparison of academic performance prior to this course revealed no statistically significant difference in the mean GPAs of the 2 groups (3.29 and 3.23, respectively, $p = .24$). Almost all of the students held bachelor degrees, with very few in either study group having graduate degrees. Age and ethnicity/race were also highly skewed, with the vast majority of students in both study groups being Caucasians younger than 30 years (Table 1).

Quiz Answer Changes After Peer-Instruction Activities (Hypothesis 1)

A single best answer, multiple-choice quiz question was administered before, and again after, each peer-instruction activity during the 20 experiment-group lectures. There were 42 peer-instruction activities performed during the 20 lectures (therefore, 42 quiz questions). There was a statistically significant main effect for the peer-instruction activity, $F(1, 93) = 6.573$, $p = .012$, $r = .257$. Answer changes after peer instruction were markedly skewed toward improved quiz scores, with 97.5% of the changes

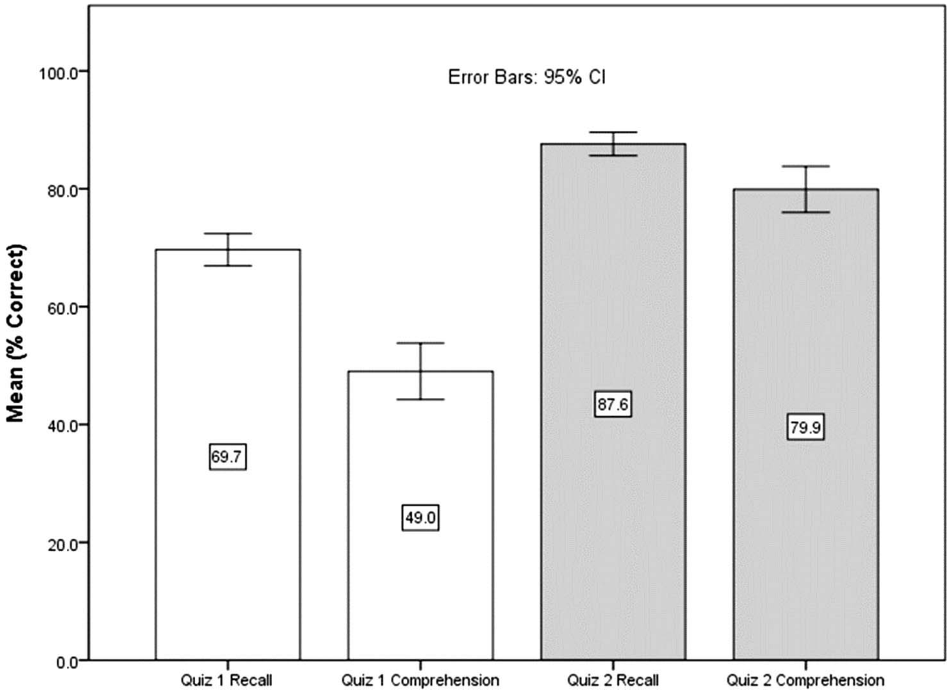

Figure 1 - Quiz scores before and after peer-instruction activities (hypothesis 1). Quiz scores before (quiz 1) and after (quiz 2) peer-instruction activities are shown. The clear bars report recall scores and the shaded bars report comprehension scores. Numbers within the bars are mean score values. The error bars are 95% confidence intervals. These data derive from 42 quiz questions (34 recall and 8 comprehension) administered only to the 102 students in the peer-instruction study group.

resulting in corrected answers. Simple-recall quiz scores were consistently higher than comprehension scores both before and after the peer-instruction activity (Fig. 1). While comprehension quiz scores increased more after the peer-instruction exercises than simple-recall quiz scores (mean score increase in comprehension, 30.9 points; in recall, 17.9 points), this peer-instruction activity/question type interaction did not reach a statistically significant level, $F(1, 93) = 0.098$, $p = .755$, $r = .03$. Similarly, there were no statistically significant interactions with sex and ethnicity.

Final-Exam Scores Compared Across Control and Peer-Instruction Groups (Hypothesis 2)

The cumulative final exam comprised 60 single best answer, multiple-choice questions (47 simple-recall MCQs and 13 comprehension MCQs) that were equally divided across the immunology and endocrinology topics. Mean scores with 95% confidence intervals are shown in Table 2 and Figure 2.

Both study group and question type demonstrated substantial main effects that were statistically significant: study group, $F(1, 193) = 9.264$, $p = .003$, $r = .214$; question type, $F(1, 193) = 26.671$, $p = .000$, $r = .348$. The peer-instruction group had higher final-exam scores than the control group, and students scored higher on recall questions than on comprehension questions in both study groups (Fig. 2). The mean score difference between the control and peer-instruction group scores was greater for comprehension questions than for recall questions (group differences: comprehension, 8.4 points; recall, 4.7 points). Although this group X question type interaction was borderline with regard to statistical significance in our study ($F(1, 193) = 3.905$, $p = .050$, $r = .141$), we believe the difference (3.7 percentage points) is pedagogically meaningful. Sex and ethnicity did not exert statistically significant main or interactive effects.

Table 2 - Final-Exam Scores

Group	Q Type	% Mean Score	Lower 95% CI	Upper 95% CI
Control	Recall	81.8	79.4	84.2
	Compr	54.6	51.1	58.1
Peer instruction	Recall	86.5	84.4	88.6
	Compr	63.1	59.7	66.5

Q = question; CI = confidence interval; Compr = comprehension.

DISCUSSION

In this study, we evaluated the effectiveness of an active-learning exercise, peer instruction during lecture pauses. Peer instruction is a research-based instructional strategy developed by Eric Mazur[29] at Harvard University in the 1990s. Correct quiz question responses increased in 97.5% of the changes made by students after peer instruction. As anticipated, this effect was greater for comprehension quiz questions than simple-recall quiz

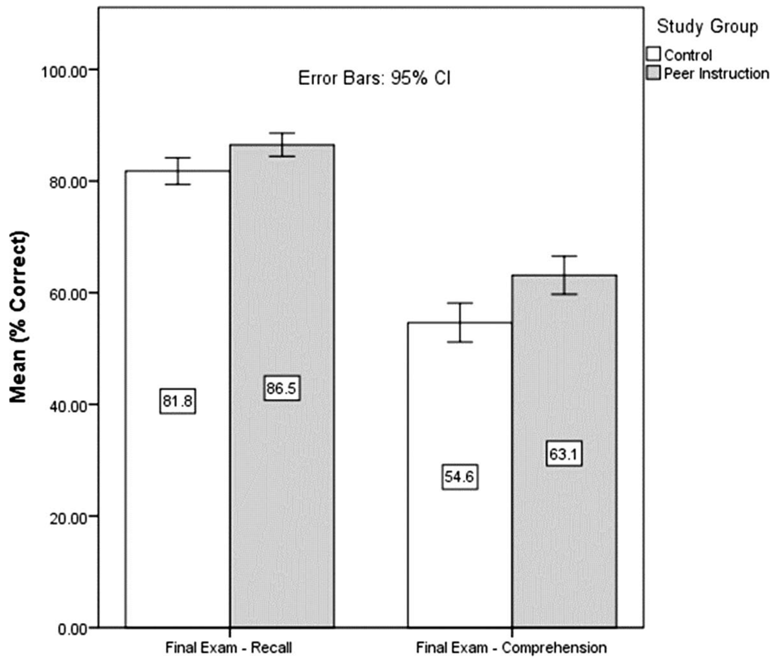

Figure 2 - Final exam scores (hypothesis 2). Mean recall and comprehension question scores from the cumulative final exam are reported for all students in the study, 96 control (clear bars) and 102 peer instruction (shaded bars). The error bars are 95% confidence intervals.

questions (hypothesis 1), but the effect was not statistically significant. These findings are generally consistent with reports by Rao and DiCarlo[30] and Linton et al,[31] although the effect of question type was larger in those studies and was statistically significant.

Prince[32] summarized the literature on collaborative learning and concluded that collaboration "works" for promoting a broad range of student-learning outcomes. In particular, collaboration enhances academic achievement, student attitudes, and student retention. Prince concluded, "The magnitude, consistency and relevance of these results strongly suggest that engineering faculty promote student collaboration in their courses."[32] Crouch and Mazur[33] analyzed 10 years of teaching a single calculus-based physics course at Harvard using peer instruction. They reported that peer instruction improved student mastery of conceptual reasoning and quantitative problem solving over time in a variety of contexts and also found that the number of students giving correct answers to concept retest substantially increased after peer discussion. They noted that peer discussion is critical to the success of peer instruction, and it encourages active engagement by students with the subject matter, a condition Crouch and Mazur feel is necessary for the development of complex reasoning skills.[33]

A major finding of our study was that cumulative final-exam scores were significantly improved by peer instruction during lecture pauses, explaining 4.6% of the exam performance (study group main effect, $r^2 = .046$). We anticipated that peer-instruction activities during lectures would improve final-exam scores, and our finding supports this expectation (hypothesis 2). The average improvement in cumulative final-exam scores for the peer-instruction group, compared with the traditional-lecture control group, was 3.7% (mean final-exam score improvement, independent of question type). This is consistent with other studies. In a meta-analysis of 235 studies reporting exam scores and failure rates for undergraduate math, engineering, and science, Freeman et al[34] reported that average examination scores improved by about 6% in active-learning sections. This had a substantial impact on final grades. Freeman et al. observed that students in classes with traditional lecturing were 1.5 times more likely to fail than were students in classes with active learning.

We also anticipated that content comprehension would be more affected than simple recall in the final exam (hypothesis 2). This effect was suggested in our sample by higher content final-exam scores compared with simple-recall scores (Table 2 and Fig. 2), but the effect was small, with borderline statistical significance. We posit that the relatively small proportion of comprehension questions in the final exam, 13 comprehension questions (22%) vs 47 recall questions (78%), may have reduced the question type effect in our study. This is an important issue to consider, because it is possible that the influence of peer-instruction pauses during lectures on final-exam performance would be greater in exams having a greater proportion of content-oriented questions. Moreover, question type should be considered from the perspective of a continuum, rather than a simple dichotomy. Each question could be considered from its relative position on the question type continuum. Consequently, future studies investigating peer instruction during lecture pauses might evaluate the outcome of this active-learning exercise on exams with a higher proportion of comprehension questions—considered from both the relative number and position on a question type continuum.

Finally, active-learning strategies such as peer instruction appeal to the adult need for self-directed action; therefore, the role of the teacher in higher education should be to engage students in mutual inquiry rather than to simply transmit information and then assess student recall with limited examination of the student's ability to critically evaluate and synthesize content.[35] With peer instruction, students must carefully consider and react to information presented by their peers during peer instruction activities, thereby developing critical analysis and synthesizing skills.[36] Active cycles of evaluation and feedback provide learning experiences that reflect real-life situations and help students develop lifelong learning skills and attitudes.[37] Moreover, placing students at the center of instruction shifts the focus from teaching to learning and promotes a learning environment more amenable to the metacognitive development necessary for students to become independent, critical thinkers. By contrast, traditional lectures are a form of passive learning, previously described as "a listless transfer of information from professor to student focusing on memorization of content which emerged from another's thinking."[38] Compared with traditional lectures, active-learning instruction improves learning outcomes[39] and improves learning attitudes.[40]

CONCLUSION

Lectures with peer-instruction pauses increase student recall and comprehension compared with traditional lectures. Cumulative final-exam scores were significantly improved following peer instruction during lecture pauses. Content comprehension may be more affected by this method than simple recall; however, while this was suggested in our sample, the effect was small, with borderline statistical significance.

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